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Impact of wormholes and cm-scale distributions of biodegradation potential on simulated pesticide leaching through loamy agricultural soil

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Pesticides are increasingly being detected in the groundwater despite being biodegradable. The large cm-scale variation in the degradation potential and rapid preferential solute transport through e.g. wormholes in agricultural loamy soils could be the causes of the unexpected pesticide leaching to groundwater aquifers.
Three-dimensional numerical simulations were conducted using COMSOL Multiphysics to evaluate how cm-scale spatial heterogeneity affects the leaching of the phenoxy acid herbicide MCPA through the upper metre of a variably-saturated, loamy soil profile. Realistic spatial variation in degradation potential was incorporated in the model using data from a site in Denmark, where 420 mineralization curves over 5 depths have been measured. Monod kinetic models were fitted to the individual curves to derive 3-D initial degrader biomass distributions for the upper metre. These were incorporated in a reactive transport model to simulate heterogeneous biodegradation. Six leaching scenarios were set up using COMSOL Multiphysics to evaluate the difference between models having different degrader biomass distributions (homogeneous, heterogeneous, or no biomass) and either matrix flow or preferential flow through a soil matrix with a wormhole. As upper boundary condition netprecipitation representing a period May - December was used with an application of MCPA on May 2 as a flux of maximum allowed dose. The simulation results showed that cm-scale heterogeneity in degradation potential does not impact the overall MCPA-leaching to one metre depth in loamy soil under a typical agronomic regime given a generally high degradation potential in the plough layer. Rapid preferential MCPA-transport through wormholes can, however, result in a bypass of this layer and the microbially active lining of a wormhole, increasing the risk of MCPA reaching the groundwater aquifer.